HAWAII PRECIPITATION FREQUENCY PROJECT

Update of *Technical Paper No. 43*

Twenty-second Progress Report
1 July 2006 to 30 September 2006

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
National Oceanic and Atmospheric Administration
Silver Spring, Maryland

October 2006

DISCLAIMER

The data and information presented in this report are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

Table of Contents

1. Introduction 4
2. Highlights 6
3. Progress in this Reporting Period.. 7
4. Issues.. 18
5. Projected Schedule and Remaining Tasks.. 19
References... 20

HAWAII PRECIPITATION FREQUENCY PROJECT

Update of *Technical Paper No. 43*

1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development of NOAA's National Weather Service plans to update its precipitation frequency estimates for Hawaii. Current precipitation frequency estimates for Hawaii are contained in *Technical Paper No. 43,* "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years" (U.S. Weather Bureau, 1962) and *Technical Paper No. 51*, "Two- to Ten-Day Rainfall for Return Periods of 2 to 100 Years in the Hawaiian Islands" (U.S. Weather Bureau, 1965). The update includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The project will determine annual precipitation frequencies for durations from 5 minutes to 60 days, for average recurrence intervals from 1 to 1,000 years. The project will review and process rainfall data for the project area and use accepted statistical methods. The project results will be published as Volume 4 of NOAA Atlas 14 on the Internet (http://www.nws.noaa.gov/ohd/hdsc) using web pages with the ability to download digital files.

The project area covers the Hawaiian Islands including Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai. The project area including preliminary regions is shown in Figure 1.

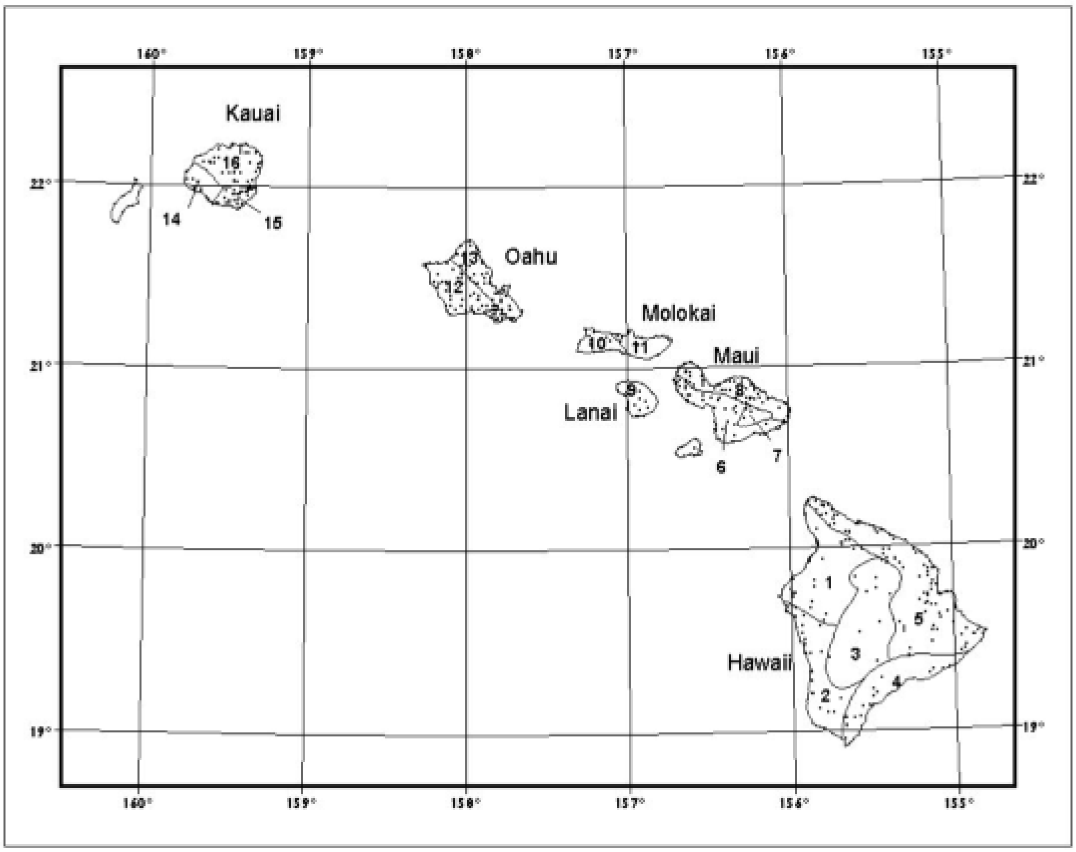


Figure 1. Hawaii Precipitation Frequency Project area, preliminary regional divisions and daily station locations.

2. Highlights

Initial quality control of the daily, hourly and n-minute data is complete. Additional 15-minute data will be obtained from the USGS and reviewed for inclusion in the project. This quarter, quality control of the annual maximum dataset using *QCseries* was completed on the 24-hour, 48-hour and 2-hour durations. Quality control of values above thresholds was completed on the 60-minute and 120-minute durations. In addition, annual maximum series were screened for anomalously low annual maximums and gaps in record. Additional information is provided in Section 3.1, Data Collection and Quality Control.

Wet seasons were assigned to each region for the purpose of extracting meaningful annual maximum series. Additional information is provided in Section 3.2, Series Extraction.

Several data issues were resolved. Inconsistencies observed between the daily and hourly period of records of 35 co-located stations were mitigated. After a thorough investigation, the decision was made to treat daily stations with large amounts of accumulated data as supplemental data that is not used in the computation of regional parameters. Additional information is provided in Section 3.3, Data Issues.

After appending data to daily co-located stations, the merging of stations was reassessed for both daily and hourly stations. There were 38 sets of daily stations meeting specific distance, elevation and period of record criteria that were merged and 10 sets of hourly stations. Additional information is provided in Section 3.4, Station Merges.

Some values at various durations exceed the previously allowable maximum of 99.99 inches in HDSC software due to accumulated data. Therefore, software was modified to accommodate this additional field width. Additional information is provided in Section 3.5, Software.

The 2-year 24-hour maps from Technical Paper 43 were digitized and used to make objective comparisons with the preliminary station-based 24-hour mean annual maximum (~2.5 year recurrence interval) values as an additional quality control measure. Additional information is provided in Section 3.6, Spatial Interpolation.

HDSC continuously monitors the hits, integrity and performance of the Precipitation Frequency Data Server (PFDS), the on-line portal for all NOAA Atlas 14 deliverables and information. Additional information is provided in Section 3.7, PFDS.

Work continues on the development of geographically fixed Areal Reduction Factors (ARFs) for area sizes of 10 to 500 square miles and durations of 30-minutes to 48-hours for the United States. Additional information is provided in Section 3.8, Areal Reduction Factors.

On August 17th, 2006, HDSC released NOAA Atlas 14 Volume 2 Version 3, Precipitation Frequency Estimates for the Ohio River Basin and Surrounding States including Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. This is an update to Volume 2 Version 2. Additional information is provided in Section 4.1, Update of NOAA Atlas 14 Volume 2.

3. Progress in this Reporting Period

3.1 Data Collection and Quality Control

HDSC is pursuing additional 15-minute data from the United States Geological Survey (USGS). These data will be formatted and evaluated for inclusion in the project. Initial quality control of all other daily, hourly and n-minute data is complete. However, an interesting and valuable aspect of the analysis process, including spatial interpolation, is that throughout the process there are interim results and measures which allow additional evaluation of data quality. At each step, these measures indicate whether the data conform to the procedural assumptions. Measures indicating a lack of conformance will be used as flags for data quality and we will review the data accordingly.

During this reporting period, quality control of the annual maximum dataset using *QCseries* was completed on the 24-hour, 48-hour and 2-hour durations. *QCseries* is an objective technique that performs a spatial and statistical evaluation against concurrent data at nearby stations. Values flagged by *QCseries* were investigated further against climatological data bulletins, scanned observation records, nearby stations, surrounding durations and publications such as “Storm Data” to determine their validity. Fifty-seven 24-hour values, fifty-three 48-hour values, and ninety-nine 2-hour values were verified. One correction was made to the 48-hour dataset and seven to the 2-hour dataset.

N-minute and 15-minute (NCDC and Hydronet) data were accumulated to 60-minute and 120-minute summations so they could be efficiently quality controlled by comparing with 1-hour and 2-hour hourly data. Quality control of values above thresholds was completed on these 60-minute and 120-minute durations. A total of 168 values were checked resulting in 24 corrections.

The validity of the lowest annual maxima in the time series data of the 1-hour, 1-day, 10-day and 45-day durations was reviewed. The 10-day and 45-day durations were included to screen the large amounts of weekly and monthly accumulated data. Cases where the lowest annual maximum and the second lowest annual maximum were more than 35% different were checked for data quality. This afforded the opportunity to find years where a given station was missing data on days during which a high precipitation event occurred at other stations. In such cases a determination was made to set that given year to missing rather than retain a probably erroneous low annual maximum caused by data sampling. Out of approximately 50 stations that were checked, there were 14 corrections.

Large gaps (i.e., sequential missing years) in the 1-day and 30-day annual maximum series of stations were screened since it was not possible to guarantee that the two given data segments were from the same population (i.e., same climatology, same rain gauge, same physical environment). The 30-day was included to screen the large amounts of accumulated data because many such stations have annual maximum series for only 30-day and longer but not 1-day. The screening process assures data series consistency before the data are used. Station records with large gaps (more than 10 years) were flagged and examined on a case-by-case basis. If there were a sufficient number of years (at least 10 years of data) in each data segment, a t-test (at the 90% confidence level) was conducted to assess the statistical integrity of the data record. Nearby stations were inspected for concurrent data years to fill in the gap if they passed a statistical test for consistency. To produce more congruent data records for analysis, station record lengths were adjusted where appropriate. Eleven records were adjusted during this check.

3.2 Series Extraction

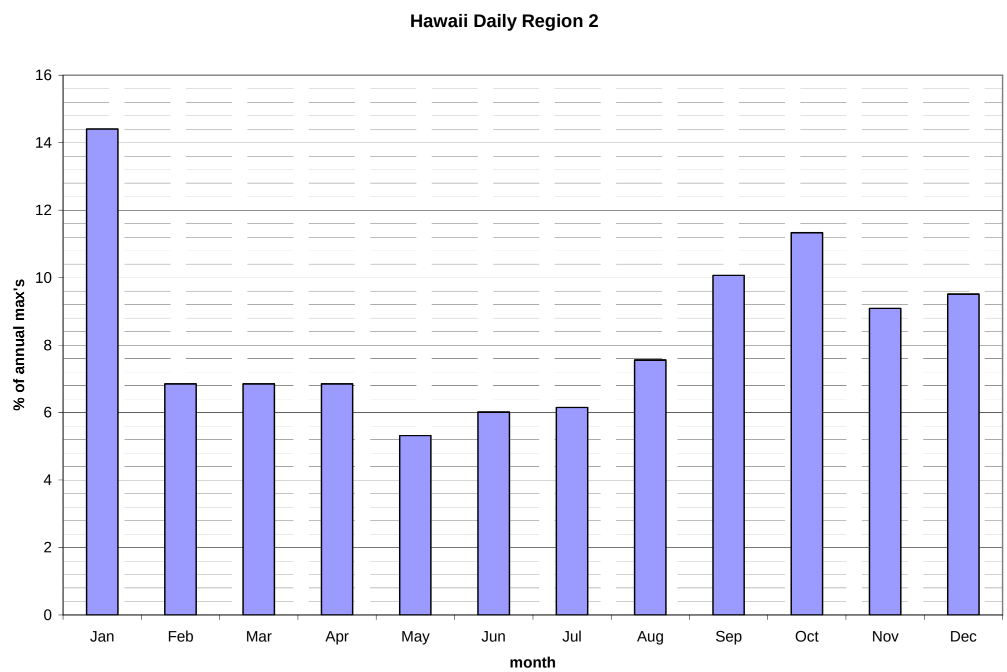
The procedure for extracting maxima from the dataset uses specific criteria. The criteria ensures that each year has a sufficient number of data, particularly in the assigned "wet season", to accurately extract statistically meaningful values. The wet season for each location is defined as the months in which extreme cases are mostly likely to occur and was assigned by assessing histograms of 1-day and 1-hour annual maximum precipitation in each month for each region (Table 1). Regions 3 and 7 did not have enough stations for hourly inference and so were analyzed together. The 1-day and 1-hour durations were similar enough to have one assigned wet season for daily and hourly regions as illustrated in Figure 2 which shows an example using region 2. The wet seasons will be refined as necessary during the regionalization process.

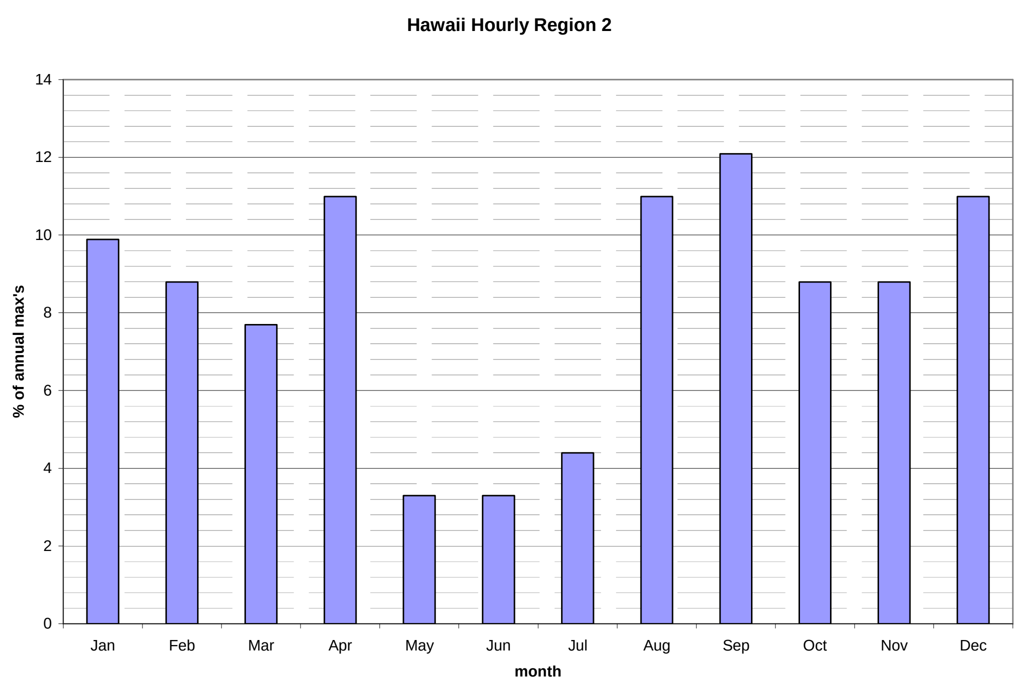
Table 1. Wet seasons for Hawaii daily and hourly preliminary regions.

Region	**Daily Wet Season**	**Hourly Wet Season**	**Assigned Wet Season**
1	10 to 4	9 to 4	**9 to 4**
2	6 to 4	8 to 4	**8 to 4**
3 and 7	7 to 4	1 to 12	**1 to 12**
4	8 to 3	7 to 5	**8 to 3**
5	7 to 5	7 to 4	**7 to 5**
6	10 to 4	8 to 5	**8 to 5**
8	11 to 4	10 to 4	**10 to 4**
9	9 to 4	10 to 3	**9 to 4**
10	10 to 3	10 to 5	**10 to 4**
11	10 to 4	10 to 3	**10 to 4**
12	10 to 4	9 to 4	**9 to 4**
13	10 to 5	8 to 3	**8 to 5**
14	10 to 3	10 to 4	**10 to 4**

15	8 to 5	10 to 5	**8 to 5**
16	8 to 5	9 to 5	**8 to 5**

Figure 2: Daily and hourly annual maximum histograms used to assess wet seasons for preliminary region 2.





3.3 Data Issues

Co-located station records. Inconsistencies were observed between the recording periods of 35 daily and hourly co-located stations. Table 2 lists the stations and the inconsistent periods of records. This could lead to inconsistencies, particularly if the periods sampled were climatologically different (i.e., the hourly sampled a wet period while the daily sampled a dry period). To ensure consistency between the data series, 24-hour accumulated data from the co-located hourly stations were appended as daily data to their corresponding daily stations for the period where the hourly station had a longer record.

Table 2. Inconsistent data periods of records at co-located daily and hourly stations.

Station ID	Daily record	Hourly record
51-0145	07/1942 - 10/2000	03/1965 - 11/2001
51-0300	01/1956 - 04/1978	05/1965 - 12/2004
51-0541	01/1991 - 10/2003	03/1965 - 12/2004
51-1008	04/1957 - 08/1975	03/1965 - 09/1976
51-1122	05/1907 - 04/1978	03/1965 - 02/1979
51-1384	01/1942 - 04/1978	04/1966 - 04/1979
51-1487	05/1970 - 04/1978	04/1970 - 03/1982
51-1540	06/1965 - 03/1976	05/1965 - 12/2004
51-1924	10/1949 - 11/1976	04/1963 - 12/1976
51-1960	05/1911 - 04/1978	03/1965 - 10/1993
51-2270	05/1985 - 01/1987	02/1986 - 02/1987
51-2570	01/1905 - 12/1973	05/1965 - 12/2004
51-2683	01/1959 - 04/1978	05/1965 - 12/2004
51-3159	07/1940 - 04/1978	01/1966 - 12/2004
51-4193	04/1964 - 02/1982	12/1976 - 03/1983
51-4272	01/1905 - 10/2000	03/1965 - 12/2004
51-4764	10/1949 - 12/1978	03/1965 - 08/1981
51-4778	01/1905 - 03/1978	04/1965 - 12/2004
51-5003	01/1964 - 08/1976	03/1965 - 04/1977
51-5560	11/1963 - 10/2000	03/1965 - 12/2004
51-5647	01/1941 - 08/1976	05/1965 - 09/1976
51-5781	01/1958 - 01/1969	03/1966 - 02/1969
51-5782	03/1969 - 04/1978	02/1969 - 11/1987
51-7131	10/1949 - 09/1993	07/1978 - 10/1993
51-7952	11/1976 - 04/1978	05/1977 - 03/1989
51-8063	10/1949 - 04/1978	03/1965 - 12/2004
51-8172	06/1966 - 05/1976	11/1967 - 08/1976
51-8555	10/1949 - 04/1978	03/1965 - 12/2004
51-8743	08/1978 - 03/1979	05/1977 - 04/1979
51-8945	01/1940 - 04/1978	04/1965 - 12/2004
51-8966	01/1943 - 01/1987	06/1987 - 12/2004
51-9195	01/1908 - 12/2000	03/1965 - 12/2004
51-9335	01/1953 - 04/1978	03/1965 - 12/2004

51-9376	08/1916 - 06/1979	07/1979 - 12/2004
51-9593	01/1915 - 04/1978	03/1965 - 12/2004

Accumulated daily data. Stations with large amounts of accumulated daily data were carefully assessed. Accumulated data occur when a gage was not read daily but the rainfall was collected over a period of two or more days and then recorded. Such accumulated data were generally found in more remote areas where the observer read the gage weekly or monthly, so 7-day and 30-day accumulations were most common. Reliable shorter durations cannot be extracted from such accumulations. Therefore, some stations may have longer duration annual maximums extracted but not shorter (particularly 1-day). This leads to inconsistencies in the analysis and results. Consistency is better maintained when the same stations are used for computation of the regional statistics for all durations.

The mean annual maxima (1-day, 7-day and 30-day) at these stations were found to be consistent with nearby means. However, after thoroughly evaluating the data, it was determined that the quality of the accumulated data is insufficient for computing higher order statistical moments directly. Therefore, the decision was made to treat these stations as "supplemental". Supplemental data will not be used to compute regional parameters or growth factors. Quantiles at these stations will be estimated from their mean annual maxima and the regional growth factors of the regions in which they reside. Their means and quantiles will then be included in the spatial analysis. These stations are primarily located in remote, data sparse areas and therefore including their means and quantiles will provide important spatial anchors during the spatial interpolation phase of the project.

3.4 Station Merges

The merging of daily stations was re-evaluated after appending additional co-located data to some records (see Section 3.3, Data Issues). Daily stations in the project area within 1.5 miles in horizontal distance and 1,000 feet in elevation with non-concurrent records were considered for merging to increase record length and reduce spatial overlaps. Candidate stations could not have a gap or overlap in the period of record of more than 5 years. The 1-day and 30-day annual maximum series of candidate stations were tested using a statistical t-test to ensure the samples were from the same population and appropriate to be merged.

After the re-evaluation, a total of 38 groups of daily stations were merged after meeting all criteria. Of these 38 mergers, 33 were pairs (Table 3) and 5 were 3-station groups (Table 4).

Using the same criteria, hourly stations were considered for merging. 27 pairs of hourly stations were candidates to be merged. A total of 10 groups were merged – seven pairs of stations (Table 5) and three 3- or 4-station groups (Table 6). Stations whose daily co-located counterparts were merged were also merged in the hourly dataset.

Table 3. Daily station pairs that were merged.

Station 1 (ID - Name)	**Station 2 (ID - Name)**
51-1598 HOMESTEAD FIELD 524	51-6534 MOLOKAI AP 524
51-8905 WAHIAWA 872	51-9795 WHEELER AAF 810.1
51-9800 WHEELER	53-0058 OHAU 00-081401
53-0113 OHAU 00-085400	53-0123 OHAU 00-088800
51-2683 KAILUA FIRE STN 791.3	53-0100 OHAU 00-079070
51-5785 MAKAHUENA POINT 940.1	51-4748 KOLOA LN MAK 940.1
51-6537 MOLOKOA 1015	53-0197 KAUAI 00-101600
51-0344 CITY OF REFUGE 27.4	51-8552 PUUHONUA-O-HONAUNAU 27.4
51-7421 PAHALA 21	51-7437 PAHALA MAUKA 21.3
51-4928 KUKUIHAELE HIC 199	51-4927 KUKUIHAELE 206.1
51-0260 CAMP K 3 HCS 313	53-0134 MAUI 00-031320
51-2317 KAANAPALI AP 453.1	51-2307 KAANAPALI AIRPORT 453.1
51-5006 KULA SANATORIUM 267	51-5004 KULA HOSPITAL 267
51-0232 BLACK POINT 717	51-9397 WAIKIKI 717.2
53-0074 OHAU 00-087310	51-8838 UPPER WAHIAWA 874.3
51-1527 HOAEAE UPPER	53-0064 OHAU 00-080600
51-1593 HOMESTEAD 985	53-0252 KAUAI 00-092800
51-6546 MOUNTAIN VIEW #3 91.9	51-0746 GLENWOOD NO 2 55.4
51-7204 PAAUHAU 217	51-7209 PAAUHAU MAUKA 217.2
51-8559 PUUOMALEI	51-0995 HALEAKALA EXP FARM 434
51-8601 ST STEPHEN'S SEMINARY	53-0075 OHAU 00-079060
51-8577 RESERVOIR 9 307	51-8060 POHAKEA BRIDGE 307.2
51-1562 HOLUALOA BEACH 68	51-2686 KAILUA HEIGHTS
51-4632 KIPA	51-0150 AMAUULU 89.2
51-8378 PUUKAELE RESERVOIR 1135	51-4566 KILAUEA FIELD 17 1135
51-3754 KAWAILOA	53-0116 OHAU 00-089000
51-0300 CAMP 84 807	53-0090 OHAU 00-080930
51-8126 PORTLOCK ROAD 724.4	51-7540 PAIKO DRIVE 723.4
53-0082 OHAU 00-077160	51-0123 AIEA HEIGHTS 764.6
51-1370 HEEIA	51-3113 KANEOHE MAUKA 781
53-0127 HI OHAU 00-089200	51-9603 WAIMEA ARBORETUM 892.2
51-1960 HONOMU MAUKA 138	51-2595 KAHUNA FALLS 138.2
51-8972 WAIAKAMOI DAM 336	51-9335 WAIKAMOI DAM 336

Table 4. Daily 3-station groups that were merged.

Station 1 (ID - Name)	Station 2 (ID - Name)	Station 3 (ID - Name)
51-8734 TANTALUS 714	51-8736 TANTALUS MAUKA	51-8738 TANTALUS 2 780.5
51-5213 LAIE 903	51-0340 CHURCH COLLEGE LAIE	51-0242 B Y U LAIE 903.1
51-6228 MAUNAWILI RANCH	51-3123 KANEOHE RANCH 838	51-7656 PALI GOLF COURSE 788.1
51-3047 KAMAOA 5	51-3048 KAMAOA 2 5	51-3054 KAMAOA PUUEO 5.1
51-5781 MAKAHA VALLEY 800.1	51-5782 MAKAHA PUMP 800.2	51-5758 MAKAHA CTRY CLUB 800.3

Table 5. Houry station pairs that were merged.

Station 1 (ID - Name)	Station 2 (ID - Name)
51-0438 DOWSETT HIGHLANDS 780	51-0404 DOWSETT 775.4
51-9350 WAIKANONOULA 178.6	51-2600 KAHUA RANCH HQTRS 176.3
51-3220 KAPAKA MAKAI 905.1	51-8314 PUNALUU PUMP 905.2
51-3985 KEALAKEKUA 3 29.11	51-3987 KEALAKEKUA 4 74.8
51-7204 PAAUHAU 217	51-7209 PAAUHAU MAUKA 217.2
51-8743 UNIV OF HAWAII AGR RES CN	51-5000 KULA BRANCH STN 324.5
51-1960 HONOMU MAUKA 138	51-2595 KAHUNA FALLS 138.2

Table 6. Hourly 3-station and 4-station groups that were merged.

Station 1 (ID - Name)	Station 2 (ID - Name)	Station 3 (ID - Name)	
51-3056 KAMEHAME 724.7	51-2842 KALAMA VALLEY 724.13	51-1308 HAWAII KAI G.C. 724.19	
51-5781 MAKAHA VALLEY 800.1	51-5782 MAKAHA PUMP 800.2	51-5758 MAKAHA CTRY CLUB 800.3	
51-3561 KAUPAKULUA RESERVOIR 492.	51-1016 HALEHAKU 492.2	51-4840 KUIAHA EXP STN 490.6	51-7952 PEAHI 488.6

3.5 Software

Some values at various durations exceed the previously allowable maximum of 99.99 inches in HDSC software due to accumulated data. Therefore, software has been modified to accommodate this additional field width. The functions of the software requiring modification include data series extraction, L-moment analysis, internal consistency adjustment, and confidence limit computation, among others. Most changes are complete, but modification continues into the next quarter on additional software functions needed for the analysis.

3.6 Spatial Interpolation

As part of the establishment of a high quality station dataset, the 2-year 24-hour maps from Technical Paper 43 were digitized, converted into GIS grids and subsequently used to make objective comparisons with the preliminary station-based 24-hour mean annual maximum (~2.5 year recurrence interval) values. These comparisons, coupled with other measures, have revealed questionable data values that we are investigating.

3.7 PFDS

HDSC continuously monitors the hits, integrity and performance of the PFDS, which continues to receive a steady number of hits per month. The graph (Figure 3) below summarizes the number of individual data inquires made since June 2004, while the map (Figure 4) indicates the locations of inquires during the past quarter.

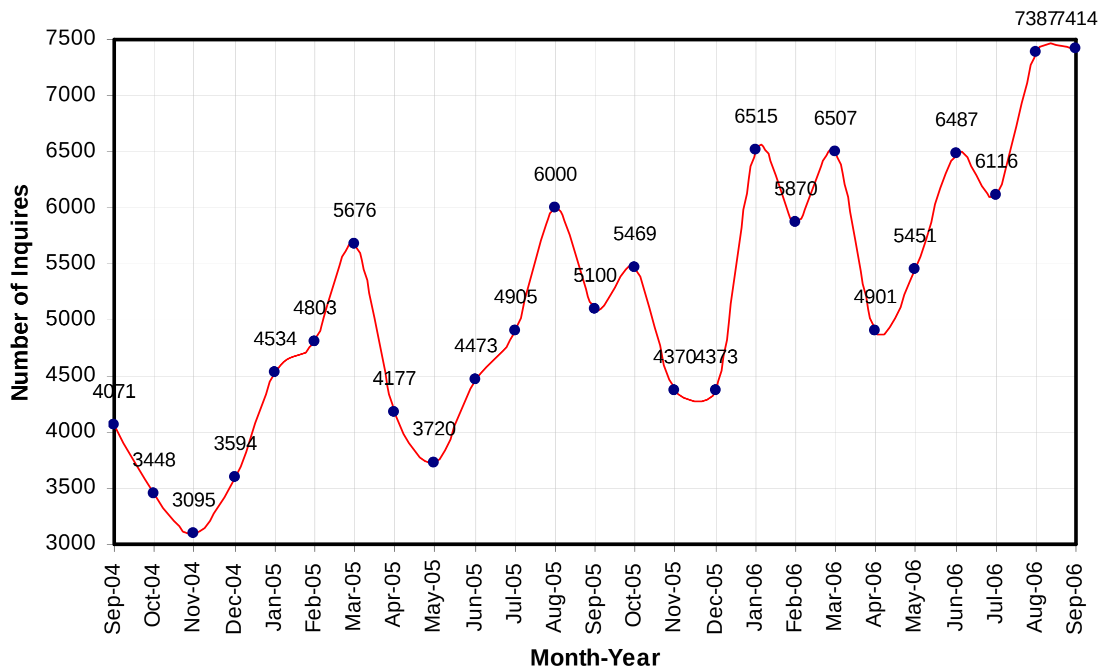


Figure 3: Number of individual PFDS data inquires per month.

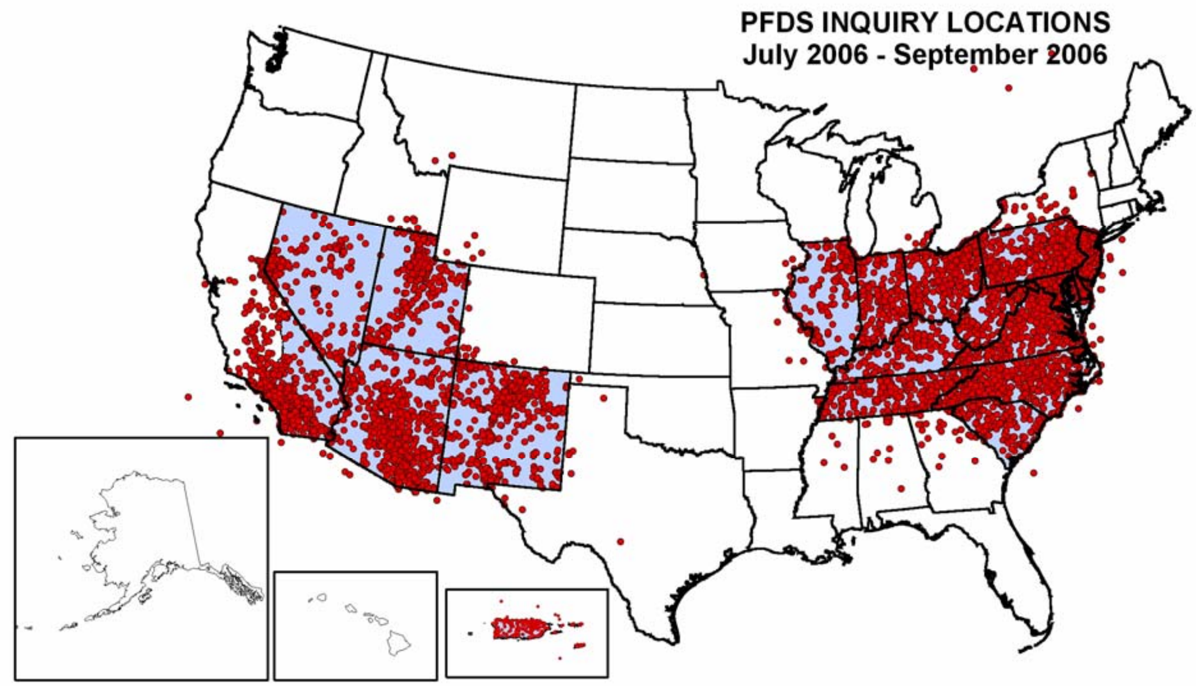


Figure 4: Map of 16,839 PFDS data inquiry locations during the period July-September 2006.

3.8 Areal Reduction Factors

Work continues in the development of geographically fixed Areal Reduction Factors (ARFs) for area sizes of 10 to 500 square miles and durations of 30-minutes to 48-hours for the United States. The results of this supplementary study will be applicable to all volumes of NOAA Atlas 14.

Although ARF software development has been slow, it continues to move forward. The continuing goal is to develop ARF software based on the NOAA Technical Report NWS 24 (Myers, V.A. and R.M. Zehr, 1980) methodology and obtain the same results published in TR-24 for the Chicago rain gauge network. The ARF computations are a function of six variables that vary in time and space. Fitting functions (curves) to these six variables so that the results are equal to those in TR-24 has been difficult.

Figure 5 shows the locations of all used, not used and considered rain gauge networks. Table 7 provides additional details of the preliminary study areas. In order to be included in the analysis, the networks must meet certain criteria (~10+ years of concurrent hourly precipitation data at 10+ gauges over an area of ~100 to ~500 square miles). We have identified, pre-processed and quality controlled hourly precipitation data for 15 networks that we believe will anchor the final ARF results. Seven additional networks are being considered, but are likely not going to be used due to short periods of record, small area sizes, questionable data quality or a combination of these.

Figure 5. Map of ARF study areas.

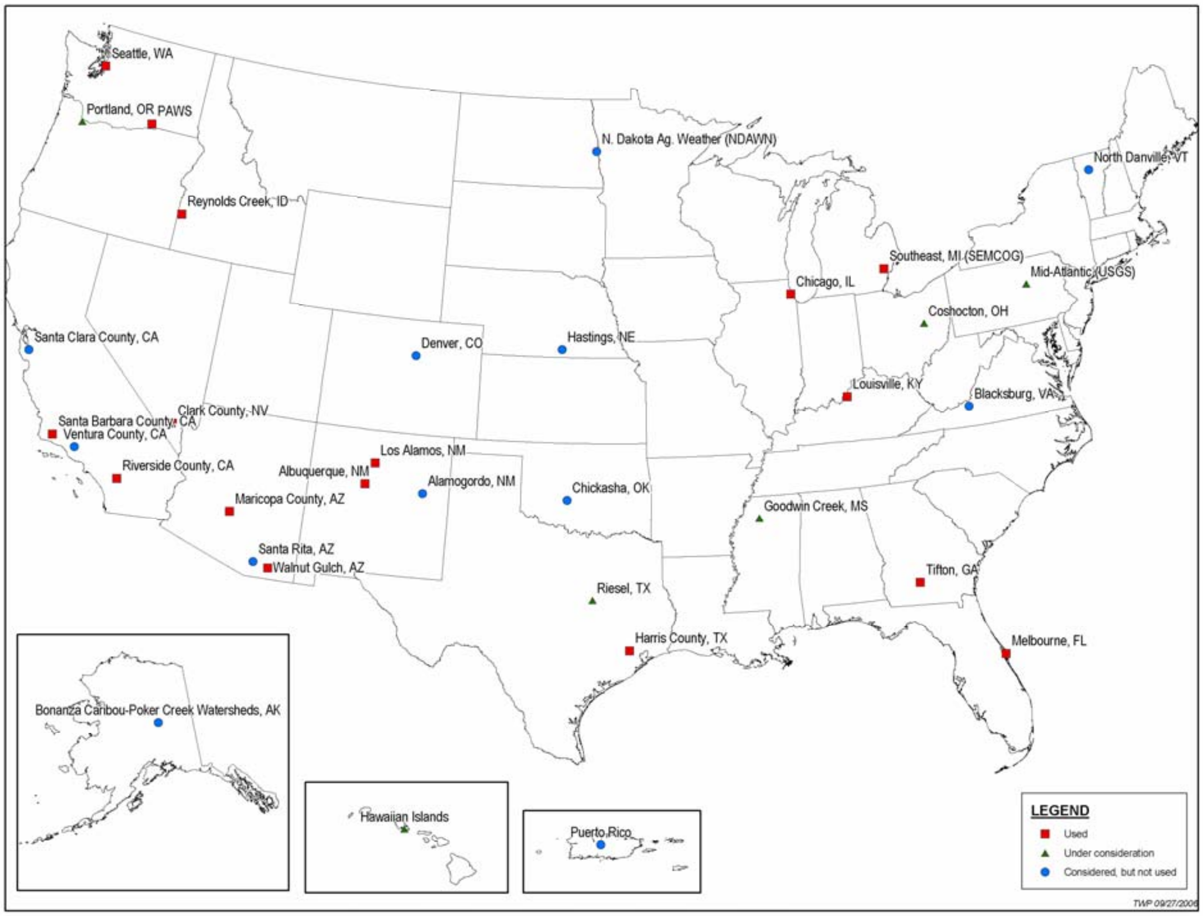


Table 7. Preliminary ARF study areas.

Study area location	Included?	Date Range	Approx size (sq-mi)	No. of stations	Lat.	Long.	Average Elevation (ft)
Albuquerque, NM	Yes	1978-1992	400	13	35.161	-106.566	5311
Chicago, IL	Yes	1949-1980	n/a	18	41.830	-87.692	618
Clark County, NV	Yes	1990-2004	n/a	48	36.290	-114.978	940
Los Alamos, NM	Yes	1990-2005	150	9	35.858	-106.282	7011
Maricopa Cty, AZ	Yes	1980-2001	n/a	31	33.789	-112.303	2572
Reynolds Creek, ID	Yes	1962-1996	n/a	44	43.169	-116.769	5342
Riverside Cty, CA	Yes	1961-2001	n/a	45	33.793	-116.995	1987
Santa Barbara, CA	Yes	1968-2003	n/a	38	34.590	-119.957	1203
Seattle, WA	Yes	1978-2003	216	23	47.553	-122.333	152
South-central Washington state (PAWS)	Yes	1989-2005	700	15	46.071	-119.306	765
Southeast Michigan Council of Governments (SEMCOG)	Yes	1988-2002	n/a	50	42.518	-83.286	730
Melbourne, FL	Yes	1997-2005	450	35	28.545	-80.634	0
Harris County, TX	Yes	1997-2005	3800	165	29.779	-95.405	-999
Walnut Gulch, AZ	Yes	1954-1996	n/a	107	31.728	-110.024	4656
Jefferson County, KY	Yes	1991-2005	n/a	18	38.190	-85.670	-999
Chickasha (Micronet), OK	Maybe	1994-2005	1130	44	34.885	-98.075	398
Coshocton, OH	Maybe	1940-2001	n/a	22	40.435	-81.799	1044
Goodwin, MS	Maybe	1981-1996	n/a	32	34.232	-89.914	333
Portland, Oregon HYDRA	Maybe	1976-2005	200	45	45.537	-122.662	-999
Tifton, GA	Maybe	1968-1981	n/a	55	31.439	-83.590	-999
Ventura, CA	Maybe	n/a	n/a	134	34.370	-119.067	-999
Hawaii	Maybe	1948-2005	n/a	n/a	n/a	n/a	n/a
Alamogordo Creek, NM	No	1955-1962	67	64	34.920	-104.143	4898
Blacksburg, VA	No	n/a	n/a	<10	37.250	-80.417	-999
Denver, CO	No	n/a	n/a	n/a	39.750	-105.000	-999
Ft. Collins, CO	No	1999-2005	12		40.567	-105.093	5099
Riesel, TX	No	n/a	10	39	31.482	-96.880	544
Hastings, NE	No	1938-1967	n/a	19	40.255	-98.376	-999
North Danville, VT	No	1958-1975	n/a	27	49.678	-74.724	2118
Puerto Rico	No	1973-2003	500	10-18	18.260	-65.910	800
Mid-Atlantic DCP and Metar network	No	1990-2004					
Bonanza, Caribou-Poker Creeks Watersheds, AK	No	n/a	50	n/a	64.750	-148.230	1641

4. Issues

4.1 Update of NOAA Atlas 14 Volume 2

On August 17th, 2006, HDSC released NOAA Atlas 14 Volume 2 Version 3, an update to Version 2. Volume 2 contains precipitation frequency estimates for the Ohio River Basin and Surrounding States including Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia.

The Version 3 update represents an enhanced product that has added estimates for the 1-year average recurrence interval (ARI). In addition, it incorporates some enhanced algorithms based on lessons learned in creating the newest volume, Volume 3 (Puerto Rico and the U.S. Virgin Islands). Each of the additions and enhancements were objectively justified and based on sound science. The enhancements include improved spatial interpolation when using the inverse-distance-weighting function, improved consistency adjustments for co-located daily and hourly stations and for hourly-only stations, and an improvement to the 24-hour confidence limits. An Addendum is available to provide additional details. It is available on our web site: http://hdsc.nws.noaa.gov/hdsc/pfds/docs/NOAA_Atlas_14_Volume2_Version3_Addendum.pdf Final associated documentation will be updated accordingly and released in the next quarter.

4.2 Recent Presentations

Bingzhang Lin presented a paper, *Regional Frequency Studies of Annual Extreme Precipitation in the United States based on Regional L-moments Analysis*, at the 2006 World Environmental and Water Resources Congress in Omaha Nebraska on May 21-26, 2006 hosted by the American Society of Civil Engineers.

A poster, *NOAA Atlas 14: The new precipitation frequency atlas for California*, was presented at the California and the World Ocean 2006 conference in Long Beach, California on September 17-20, 2006. Attendees at the conference included the Governors of California, Oregon and Washington States, the Undersecretary of Commerce for NOAA Vice Admiral Conrad C. Lautenbacher, Jr. and two NOAA Assistant Administrators, Mary Glackin of the Office of Program Planning and Integration and Jack Dunnigan of the National Ocean Service, among others.

A poster, *NOAA Atlas 14: The new precipitation frequency atlas for the U.S.*, was shown at the NWS Open House in Chanhassen, Minnesota on September 26, 2006 by Pedro Restrepo, the Office of Hydrology’s Senior Scientist. The Open House was open to the general public, and was attended by an estimated 2000 people.

5. Projected Schedule and Remaining Tasks

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks that will be worked on during the next few quarters are also included in this section.

Data Collection and Quality Control [October 2006]
L-Moment Analysis/Frequency Distribution [December 2006]
Trend Analysis [January 2007]
Temporal Distributions of Extreme Rainfall [February 2007]
Peer Review of estimates [February 2007]
Spatial Interpolation [May 2007]
Precipitation Frequency Maps [June 2007]
Web Publication [May 2007]
Documentation [June 2007]

Areal Reduction Factors [January 2007]

5.1 Data Collection and Quality Control.

15-minute data from the USGS will be evaluated for inclusion in the project. Conversion factors (1-day to 24-hour, 2-day to 48-hour, 1-hour to 60-minute and 2-hour to 120-minute) will be calculated.

5.2 L-Moment Analysis

Homogeneous precipitation frequency regions for the L-Moment analysis of the 24-hour data will be created. The initial daily regions (Figure 1), which are based primarily on climatology, will be used as a starting point. Work will also begin on the hourly regions based on the 60-minute data. Software to treat supplemental longer duration data will be refined.

5.3 Trend Analysis and Cross-correlation Analysis

We will begin to analyze the 1-day annual maximum time series for trends and cross-correlation between stations.

5.4 Areal Reduction Factors (ARF)

Computations for the ARF curves will be completed in the next quarter for 14 areas. The resulting curves will be tested for differences to determine if a single set of ARF curves is applicable to the entire U.S. or whether curves vary by region.

References

Bell, F.C., 1976: The areal reduction factors in rainfall frequency estimation, Natural Environmental Research Council (NERC), Report No. 35, Institute of Hydrology, Wallingford, U.K. 25pp.

Bonnin, G., D. Todd, T. Parzybok, B. Lin, D. Riley, and M. Yekta, 2004: Precipitation frequency atlas of the United States. NOAA Atlas 14 Volume 1, Silver Spring, Maryland. http://hdsc.nws.noaa.gov/hdsc/.

Chow, V.T., D.R. Maidment, and L.W. Mays, 1988: Applied Hydrology. McGraw-Hill International Editions, 572 pp.

Frederick, R.H., V.A. Myers and E.P. Auciello, 1977: Five to 60-minute precipitation frequency for the Eastern and Central United States, NOAA Technical Memo. NWS HYDRO-35, Silver Spring, MD, 36 pp.

Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Weather Bureau Technical Paper No. 40*, U.S. Weather Bureau. Washington, D.C., 115 pp.

Himmelblau, D.M., 1970: “Sign Test for Median Difference in Paired Observations”, *Process Analysis by Statistical Methods*, page 68.

Hosking, J.R.M. and J.R. Wallis, 1997: *Regional frequency analysis, an approach based on L-moments*, Cambridge University Press, 224 pp.

Huff, F. A., 1990: Time Distributions of Heavy Rainstorms in Illinois. Illinois State Water Survey, Champaign, 173, 17pp.

Institution of Engineers, Australia, 1987: *Australian Rainfall and Runoff, 3rd Edition*, The Institution of Engineers, Australia. Canberra.

Lin, B. and L.T. Julian, 2001: Trend and shift statistics on annual maximum precipitation in the Ohio River Basin over the last century. Symposium on Precipitation Extremes: Prediction, Impacts, and Responses, 81st AMS annual meeting. Albuquerque, New Mexico.

Miller, J.F., 1965: Two- to Ten-Day Rainfall for Return Periods of 2 to 100 years in the Hawaiian Islands, *Technical Paper No. 51*, U.S. Weather Bureau, 34 pp.

Miller, J.F., R.H. Frederick and R.J. Tracy, 1973: Precipitation-frequency atlas of the western United States, *NOAA Atlas 2*, 11 vols., National Weather Service, Silver Spring, MD.

Myers, V.A., and R.M. Zehr, A Methodology for Point-to-Area Rainfall Frequency Ratios, NOAA Technical Report NWS 24, Office of Hydrology, National Weather Service, Silver Spring, Maryland, February 1980.

Spiegel, M.R., 1961: "Tests of Significance Involving Sample Differences", *Theory and Problems of Statistics*, pages 170-171.

U.S. Weather Bureau, 1962: Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years, *Weather Bureau Technical Paper No. 43*, U.S. Weather Bureau. Washington, D.C., 60 pp.